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Recent results from the Swift Supergiant Fast X–ray Transients Project

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Abstract. We present the most recent results from our Supergiant Fast X–ray Transients project. Since 2007 *Swift* has contributed to this new field by detecting outbursts from these fast transients with the *Swift*/BAT and following them for days with the XRT. Furthermore, we have performed several campaigns of intense monitoring with the *Swift*/XRT, thus assessing the fraction of the time these sources spend in each phase, and their duty cycle of inactivity.

Key words. X-rays: binaries – X-rays: individual: SAX J1818.6−1703, IGR J16418−4532, XTE J1739–302, IGR J17544−2619, IGR J16479−4514, AX J1841.0−0536

1. Introduction

Supergiant Fast X–ray Transients (SFXTs) are a class of high-mass X–ray binaries characterized by flares peaking at 10^{36}–10^{37} erg s^{-1} and lasting hours as observed with IBIS/ISGRI (Sguera et al., 2005, 2006), a spectrum that can be described as a flat power-law below $\sim$ 10 keV with exponential cutoff, a large (3–5 orders of magnitude) dynamic range in their X–ray light curves, and a firm association with OB supergiant companions.

Since 2007 our SFXT Project[1] has been exploiting the unique fast-slewing capability, broad-band energy coverage, and flexible observing scheduling of *Swift* (Gehrels et al., 2004) to perform a systematic study of these objects with a strategy that combines monitoring programs with outburst follow-ups (see Romano et al., 2010, and references therein). This strategy has allowed us to catch several outbursts (e.g., Romano et al., 2008; Sidoli et al., 2009c; Romano et al., 2009b; Sidoli et al., 2009a; Romano et al., 2011d) to

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[1] http://www.ifc.inaf.it/sfxt/

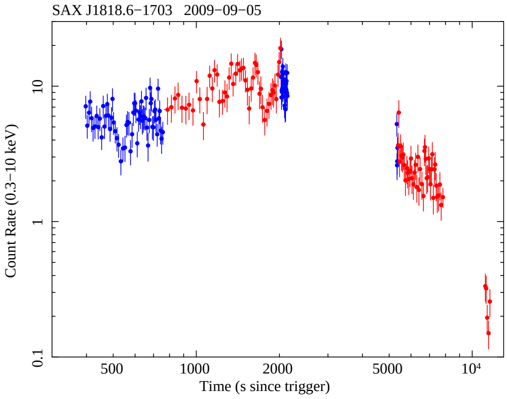

Fig. 1. Light curve of the 2009 September 5 outburst of SAX J1818.6−1703: WT (blue points) and PC (red points) data.

monitor them during their evolution, and for the very first time, to study the long term properties of this class of objects (Sidoli et al., 2008; Romano et al., 2009c, 2011c) with a highly sensitive soft X–ray telescope. In particular, our long-term monitoring of 4 SFXTs (IGR J16479−4514, XTE J1739−302, IGR J17544−2619, AX J1841.0−0536), performed with 2 or 3 observations per source per week, each 1 ks long, has allowed us to assess the fraction of the time these sources spend in each intensity phase and their duty cycle of inactivity, which ranges between 19 and 55 %, showing that these sources accrete matter for most of the time.

For this project, in order to ensure simultaneous narrow field instrument (NFI) data, the *Swift* Team devised and applied to all known SFXTs and SFXT candidates, the "BAT special functions". They allow SFXTs to trigger the BAT, make *Swift* perform a slew and then observe the source as if it were a GRB. The adoption of the BAT special functions in September 2008, combined with the prompt notification of an outburst triggering the BAT, has allowed us to *i)* correctly identify the source among the GRB triggers (within minutes); *ii)* assess whether a follow-up was warranted (usually in less than 15 minutes); *iii)* launch a full *Swift* NFI follow-up campaign (often as part of the *Swift* GI program, PI P. Romano) with observations starting within an hour, or right after the automated target observation (the one including the trigger) ended. This, in turn, has allowed us to catch the outbursts while still bright in the X–ray, hence making the collected data (light curves and spectra) quite rich and worthy of a publication. In this Paper we report the preliminary analysis of the most recent outbursts discovered and followed with this strategy.

2. The 2009 September 5 flare of SAX J1818.6−1703

SAX J1818.6−1703 triggered BAT on 2009 September 5 at 11:15:15 UT (Romano et al., 2009a). The BAT event-by-event mask-weighted light curve (T−239 to T+963 s), shows weak on-going emission at the start of the data at T−240 s, a slow rise to a peak (of 0.06 ph cm^{-2} s^{-1} in the 15–350 keV band) at about T+200 s, and then a slow decrease out past T+963 s. The BAT DPH mask-weighted lightcurve (T+500 to T+2100 s; 15–195 keV) shows another slow increase to 0.04 ph cm^{-2} s^{-1} around T+1800 s with ongoing emission past the end of data at T+2100 s. The best fit to the BAT average spectrum (T+0 to T+320 s) is a simple power-law model, with a photon index $\Gamma = 2.98 \pm 0.50$.

Swift performed an immediate slew, so that XRT started observing the field at 11:21:44.0 UT (T+389.0 s). Figure 1 shows the XRT light curve of the first orbits of data; several flares are seen in the first orbit; during the last one, the source reached about 20 counts s^{-1}. This peak roughly coincides with the second rise observed by BAT. The XRT spectrum from Windowed Timing (WT) data (766–2025 s since the trigger, with a gap to include Photon Counting (PC) data) can be fit with an absorbed power law with $\Gamma = 1.6 \pm 0.2$ and $N_{\rm H} = (8 \pm 1) \times 10^{22}$ cm^{-2}. The mean 0.3–10 keV observed (unabsorbed) WT flux is $8 \times 10^{-10} (2 \times 10^{-9})$ erg cm^{-2} s^{-1}. The PC data (395–2131 s since the BAT trigger) can be fit with an absorbed power law with $\Gamma = 1.1 \pm 0.4$, $N_{\rm H} = (8 \pm 2) \times 10^{22}$ cm^{-2}, and an observed (unabsorbed) flux of $1 \times 10^{-9} (2 \times 10^{-9})$ erg cm^{-2} s^{-1}, or a luminosity of 1.5×10^{36} erg s^{-1} (at 2.5 kpc). The characteristics of this burst are con-

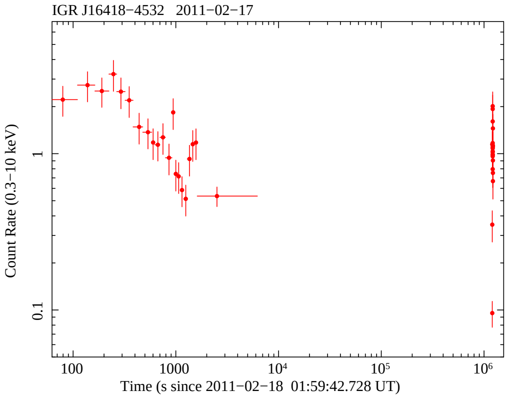

Fig. 2. Light curve of the 2011 February 17 flare of IGR J16418−4532.

sistent with the ones observed in the 2009 May 6 flare (Sidoli et al., 2009b).

3. The 2011 February 17 flare of IGR J16418−4532

A 2 ks target of opportunity observation was performed with *Swift* starting on 2011 February 18 at 01:59:43 UT (Romano et al., 2011e), following a MAXI alert (later retracted) of a possible detection of the candidate SFXT IGR J16418−4532 on 2011 February 17. By utilizing the 2 ks PC mode data, and correcting for the astrometric errors by utilizing *Swift*/UVOT data according to the method described by Evans et al. (2009), we found the best position: RA(J2000) = $16^{\rm h}\,41^{\rm m}\,50\overset{\rm s}{.}74$, Dec(J2000) = $-45^\circ\,32'\,23''\!.9$, with an uncertainty of $2''\!.3$ (90 % confidence level), thus allowing us to confirm 2MASS J16415078−4532253 (at $1''\!.5$) as the optical counterpart of this source.

The XRT data show a bright source (0.3–10 keV observed flux of 1×10^{-10} erg cm^{-2} s^{-1}). Figure 2 shows the light curve peaking at ~ 3 counts s^{-1} and the large dynamic range of ~ 50. The PC spectrum (first orbit in Figure 2) can be fit with an absorbed power-law model with $\Gamma = 2.0\pm0.5$ and $N_{\rm H} = (8\pm2)\times10^{22}$ cm^{-2} (in excess of the Galactic value, 1.59×10^{22} cm^{-2}). The average 0.3–10 keV unabsorbed flux is 3.7×10^{-10} erg cm^{-2} s^{-1}.

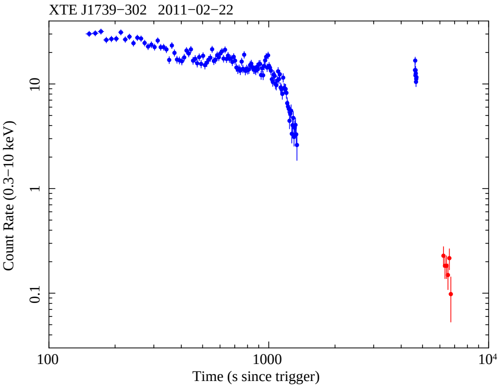

Fig. 3. Light curve of the 2011 February 22 outburst of XTE J1739−302: WT (blue) and PC (red).

4. The 2011 February 22 outburst of XTE J1739−302

BAT triggered on XTE J1739−302 on 2011 February 22 at 07:21:37 UT (Romano et al., 2011b); the slew was immediate, so that XRT imaged the field at T+141 s. The BAT event-by-event mask-weighted light curve (T−79 to T+167 s) shows that the flare started at $\lesssim T-70$ s with a slow rise. The BAT average spectrum (T+0 to T+64 s) is best fit by a simple power-law model with a photon index $\Gamma = 2.50\pm0.45$. The XRT light curve (Figure 3) shows the descending part of one bright flare that reached about 30 counts s^{-1}. The mean XRT/WT spectrum (T+147 to T+1321 s since the trigger) can be fit with an absorbed power-law with a photon index of $\Gamma = 1.18\pm0.06$ and $N_{\rm H} = (1.5\pm0.2)\times10^{22}$ cm^{-2}. The average 2–10 keV unabsorbed flux is 1.6×10^{-9} erg cm^{-2} s^{-1} and the luminosity of 1.3×10^{36} erg s^{-1} (at 2.7 kpc, Rahoui et al., 2008).

5. The 2011 March 24 outburst of IGR J17544−2619

BAT detected an outburst of IGR J17544−2619 on 2011 March 24 at 01:56:57 UT (Romano et al., 2011a); *Swift* slewed immediately, so that XRT imaged the field at T+126.4 s. The BAT mask-weighted light curve shows emission running from about T−60 to T+700 s. The mean BAT spectrum

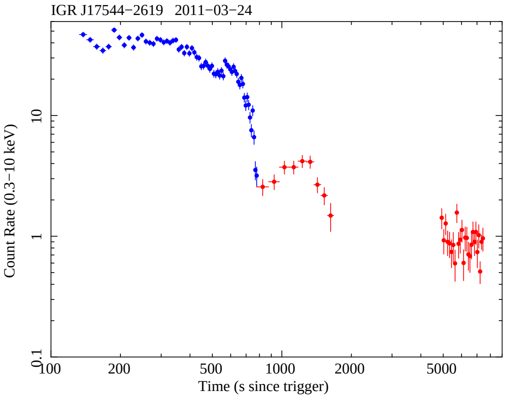

Fig. 4. Light curve of the 2011 Mar 24 outburst of IGR J17544−2619: WT (blue) and PC (red).

(T−42 to T+664 s) is best fit by a simple power-law model, with $\Gamma = 4.25 \pm 0.24$.

Figure 4 shows the XRT light curve, the descending part of one bright flare that reached 50 counts s^{-1}, a factor of two brighter than observed during the previous outburst (2010 March 4; Romano et al., 2011d). The XRT/WT spectrum (T+133 to T+783 s) can be fitted with an absorbed power law $\Gamma = 0.82 \pm 0.04$ and $N_{\rm H} = (1.0 \pm 0.1) \times 10^{22}$ cm^{-2}. The average 2–10 keV unabsorbed flux is 2.9×10^{-9} erg cm^{-2} s^{-1} and the luminosity 4.5×10^{36} erg s^{-1} (at 3.6 kpc, Rahoui et al., 2008). A power-law fit to the XRT/PC spectrum (T+784 to T+881 s) yields $\Gamma = 1.7 \pm 0.8$ and $N_{\rm H} = (2 \pm 1) \times 10^{22}$ cm^{-2} and a 2–10 keV unabsorbed flux of 1.8×10^{-10} erg cm^{-2} s^{-1}.

6. Conclusions and future perspectives

Since the adoption of the BAT special functions in September 2008 for all known SFXTs and SFXT candidates in combination with the prompt notification of SFXT outbursts triggering the BAT, we have tripled the number of outbursts followed, and studied outbursts from all 10 confirmed SFXTs where only 2 were available before our investigation began. Thanks to the *Swift* SFXT Project, it is possible to disseminate our preliminary analysis of a new SFXT outburst generally within 24 hours of the trigger, via GCNs and Astronomer's Telegrams.

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